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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume VIII - Chattanooga

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen single-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume VIII

Chattanooga, Tennessee

FINAL REPORT

by

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Contract No. 68-02-1376, Task Order No. 18

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1976

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FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an effort to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewer's comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the over all study are as follows:

Volume	I - National Assessment of the Urban Particulate Problem
Volume	II - Particle Characterization
Volume	III - Denver
Volume	IV - Birmingham
Volume	V - Baltimore
Volume	VI - Philadelphia
Volume	VII - Chattanooga
Volume	IX - Oklahoma City
Volume	X - Seattle
Volume	XI - Cincinnati
Volume	XII - Cleveland
Volume	XIII - San Francisco
Volume	XIV - Miami
Volume	XV - St. Louis
Volume	XVI - Providence

CONTENTS

		Page
Foreword		iii
List of Figures		v
List of Tables		vii
Acknowledgments		ix
Executive Summary		x
Reviewers' Comments		xiv
Sections		
I	Statement of the Problem	1
II	Analyses	10
III	Summary and Conclusions	34
Appendixes		
A	Supplementary Information	37
B	Particle Characterization	49

LIST OF FIGURES

No.		Page
1	Location of Sampling Sites in Chattanooga and Hamilton County	5
2	1974 Annual Geometric Mean TSP Concentrations	6
3	Trends in Annual Geometric Mean TSP Concentrations	8
4	1974 Citywide Mean TSP Concentrations by Day of the Week	12
5	Point Source Emissions, 1974	14
6	1974 Total Emissions Density Isopleths, TPY/km^2	15
7	Monthly TSP Versus Meteorological Variables, 1974	23
8	Annual Precipitation Versus Time	24
9	Heating Degree Days Per Season Versus Time	25
A-1	Chattanooga Fuel Burning Equipment Regulation	40
A-2	Chattanooga Process Weight Regulation	41
A-3	TSP Versus Wind Direction, Chattanooga City Hall, Site 1	42
A-4	TSP Versus Wind Direction, Chattanooga Broad Street, Site 3	43
A-5	TSP Versus Wind Direction, Chattanooga East Chattanooga, Site 6	44
A-6	TSP Versus Wind Direction, Chattanooga Shallowford Road, Site 9	45
A-7	TSP Versus Wind Direction, Chattanooga Rossville Boulevard, APC Bureau, Site 11	46

LIST OF FIGURES (continued)

No.		Page
A-8	Wind Rose for the Days on Which Sampling Took Place in 1974 - Percent of Observations	67
A-9	Rain Rose, 1974 Average Rainfall in Inches by Wind Direction	68

LIST OF TABLES

No.		Page
1	Sampling Sites and National Standards	7
2	1975 Total Emissions for Hamilton County	11
3	1974 Major Point Source Emissions by Industry Type	13
4	1950-1970 Residential Fuel Usage By Number of Dwelling Units in Hamilton County	17
5	Fuel Usage Trends in Chattanooga	18
6	TSP Versus Land Use	27
7	Sampling Site Information	28
8	Sampling Site Descriptions	30
A-1	Chattanooga - Hamilton County Air Pollution Control Regulations	38
B-1	Meteorological Data on Selected Sampling Days (Lovell Field, Chattanooga)	52
B-2	Annual Average Concentration of Sulfate and Nitrate Ions at the Chattanooga, Tennessee NASN Site No. 440380001	92
B-3a	Results of Filter Analyses for Selected Sites in Chattanooga and Vicinity (City Hall - No. 1)	93
B-3b	Results of Filter Analyses for Selected Sites in Chattanooga and Vicinity (Broad Street - No. 3)	94
B-3c	Results of Filter Analyses for Selected Sites in Chattanooga and Vicinity (Brainerd - No. 4)	95
B-3d	Results of Filter Analyses for Selected Sites in Chattanooga and Vicinity (East Chattanooga - No. 6, Silverdale - No. 7 and Shallowford Road - No. 9)	96

LIST OF TABLES (continued)

No.		Page
B-4	Composite Summary of Filter Analyses for Selected Sites in Chattanooga and Vicinity	57
B-5	Results of Replicate Analyses of Chattanooga Filters	58
B-6	Citywide Composite Summary of Filter Analyses in Chattanooga	59

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EXECUTIVE SUMMARY

AIR QUALITY LEVELS AND TRENDS

Geometric mean TSP concentrations in Hamilton County in 1974 ranged from less than 60 $\mu g/m^3$ at the monitors in suburban and undeveloped areas to around 80 $\mu g/m^3$ in the center city and industrial monitors and 100 $\mu g/m^3$ near a quarry and some truck terminals. Five of the 12 monitors exceeded the national annual primary standard of 75 $\mu g/m^3$; the 24-hour primary standard was exceeded [illegible] days (0.9 percent) at the site near the quarry and the 24-hour secondary standard was exceeded on 48 sampling days (6.9 percent) at eight of the sites. Air quality has been improving since the 1960's - geometric mean TSP concentrations decreased 110 $\mu g/m^3$ at the NASN site in the center city. An average decrease of 21 $\mu g/m^3$ occurred from 1971 to 1974 at three center city sites.

Historical data is available for only the NASN site and indicates that, in the past, air quality with respect to TSP exceeded the annual standards. This is due to the high degree of industrial activity in Chattanooga and the poor dispersion characteristics of the region. The NASN site since the 1960's and several sites in the center city and industrial areas since 1971 have experienced decreases in TSP concentrations because of fuel switching, stringent regulations and enforcement of them, and industrial process emissions control. The sampling sites in the suburban and undeveloped areas are meeting the standards but the center city and industrial sites continue to exceed them. Poor dispersion is a relatively constant influence on Chattanooga's air quality. Fugitive emissions and dust and secondary particulates have not been controlled up to the present and are

becoming a more important portion of TSP concentrations in Chattanooga as other sources are controlled.

REGIONAL SETTING

The City of Chattanooga is located in Hamilton County in the southeastern portion of Tennessee along the Tennessee-Georgia state line. The important features of Hamilton County are the Tennessee River and river valley and the ridges, mountain ranges, and valleys which run in a northeast to southwest direction. Chattanooga is surrounded by Lookout Mountain to the southwest which is 1,300 feet higher than the city, the river and several ridges to the west to north and Missionary Ridge to the east.

There is a high degree and a wide variety of heavy industrial activity, much of which is concentrated along the Tennessee River.

METEOROLOGY

Dominant features of the area include low wind speeds and frequent stagnation conditions. Mountain ridges protect valley areas and channel wind flow, and the frequent occurrence of anticyclonic flow particularly during the summer and fall months enhances the formation of nocturnal radiation inversions. As a result, dispersion conditions are frequently poor.

Chattanooga has a moderate climate characterized by cool winters and warm summers. Precipitation is moderately heavy, averaging 52 inches per year, and is distributed quite uniformly throughout the year.

Hamilton County lies near the center of the geographical region having the maximum high air pollution potential forecast days for the eastern United States.

URBAN ACTIVITY

There is a strong relationship between annual TSP concentrations and the predominant land use surrounding the monitoring sites. The amount and type of urban activity surrounding a site - residential, commercial, and industrial - helps to determine the TSP concentrations experienced there. The industrial sites averaged 90 $\mu g/m^3$ in 1974 whereas the center city site averaged 80 $\mu g/m^3$, the residential sites 52 $\mu g/m^3$, and the undeveloped site 47 $\mu g/m^3$.

REGULATIONS AND ENFORCEMENT

The Hamilton County air pollution control regulations for new industrial equipment (built or installed after 1 January 1973) are stringent but are average for existing equipment. Fugitive emissions, however, are not well controlled by the regulations. Small incinerators are allowed but their operators must be licensed. Open burning is allowed only with a permit and under certain restrictions. Surveillance and enforcement of the regulations has been rigorous - almost all of the point sources are in compliance. The procedure necessary for adopting regulations is time-consuming and involved, accounting for the difficulty in getting new regulations adopted.

EMISSIONS

Chattanooga is a highly industrial city and its industries are the most important source of particulate emissions. The sampling sites nearest the industrial areas of Chattanooga have consistently recorded the highest TSP concentrations over the past years and continue to exceed the national annual primary standards.

Considerable decreases in particulate emissions from industrial processes have occurred since 1971, the largest changes occurring with the foundries, coke plant, cement plant, and coal-fired boilers. Decreases are due to emissions controls and fuel switching.

NETWORK DESIGN

The design of the network is adequate for recording air quality in the southern portion of Hamilton County where most of the industrial, urban, and suburban areas are located but there are no sampling sites in the largely undeveloped northern portion of the county. The specific siting and exposure of the monitors seems to be generally adequate but the characteristics of the sites vary widely in ways which influence the TSP concentrations recorded. Several of the sites are located on a ridge or mountain or are separated by a ridge or mountain from the downtown developed areas of Chattanooga. Others are in or near industrial areas.

REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

Page 10 - Considering the questionable accuracy of the emission inventories it is doubtful that the statement about fugitive emissions can be substantiated.

Page 16 - The agency states that some sources, such as quarries, are controlled.

Page 18 - It must be noted that the Chattanooga-Hamilton County regulations are independent only in so far as they are no less stringent than the state's regulations.

SECTION I

STATEMENT OF THE PROBLEM

CITY CHARACTERISTICS

The City of Chattanooga is located in Hamilton County in the southeastern portion of Tennessee along the Tennessee-Georgia state line. Because of its central location in the South, Chattanooga has become an important railway and manufacturing center.

Topography and Climatology

Chattanooga is located in the southern portion of the Great Valley of Tennessee, an area where the Tennessee River flows between the Cumberland Mountains to the west and the Appalachian Mountains to the east. The Tennessee River approaches Chattanooga from the northeast, forms a loop (Moccasin Bend) north of Lookout Mountain, and continues on in a northwesterly direction. Most of the city lies to the south or east of the river - see Figure 1. Southwest of the city is Lookout Mountain, a steep-sided plateau 1,200 feet above the river. To the north and east of the city are ridges - Missionary Ridge east of Chattanooga and Stringers Ridge to the north help separate the city from the surrounding areas. The ridges, mountains and valleys in the area lie in a northeasterly to southwesterly direction.

The complex topography of the county results in weather conditions that are particularly unfavorable for the dispersion of air pollutants. The terrain tends to channel the airflow, reduce wind speeds, and enhance the

Figure 1. Location of sampling sites in Chattanooga and Hamilton County

frequency of occurrence of low-level temperature inversions. The average wind speed is only about 6 miles per hour with calms occurring about a quarter of the time. Inversions below 500 feet exist in Chattanooga about 60 percent of the nighttime hours in summer and 35 percent in winter. The typical mixing height during an inversion is 300 feet. Pools of relatively cold stable air tend to collect at night in the valleys, sheltered from wind flow by mountain ridges and causing the temperature inversions. The frequency of prolonged periods of poor dispersion conditions is greater in the Chattanooga area than in most parts of the United States. Hamilton County lies near the center of the geographical region having the maximum high air pollution potential forecast days for the eastern United States.[1]

Special meteorological reports for the Air Pollution Control Bureau show that unusually low horizontal wind speeds are not sufficient to carry off the current burden of air pollutants on about 110 days per year. Very frequent low level temperature inversions stop air pollutants from rising and mixing in the vertical direction about half the time.[1]

Chattanooga has a moderate climate, characterized by cool winters and warm, humid summers. The mountains have a sheltering effect, resulting in milder winters. January is the coldest month, averaging 40°F, and July is the warmest month at 79 degrees. The region averages 3,570 heating degree days and 1,450 cooling degree days each year.

Precipitation is moderately heavy, averaging 52 inches per year, and is fairly well distributed throughout the year. Greater amounts of precipitation occur during the winter, due to cyclonic storms from the Gulf of Mexico, and the summer, due to frequent afternoon thunder showers.

Land Use, Employment and Population Patterns

Chattanooga is the fourth largest city in the State of Tennessee with a population of 170,000 in the city and 390,000 in the metropolitan area. Aside from the city, Hamilton County is largely rural and heavily wooded with a series of small residential towns along the major highways and surrounding the city.

Chattanooga is an industrial center in which a wide variety of products are made, including explosives, chemicals, metal products, textile products, mineral products, food, and wood products.

Most of the industry is located in the center of the city and along the Tennessee River within the city due to the proximity of rail, highway and water transportation. Several large industries are located on industrial reservations outside the city.

AIR QUALITY LEVELS AND TRENDS

Sampling for suspended particulates in Hamilton County, Tennessee, takes place at 12 sites operated by the Chattanooga-Hamilton County Air Pollution Control Bureau. The locations of the sampling sites are shown in Figure 1 with identifying site numbers. Most are located in the southwestern portion of Hamilton County in and around the City of Chattanooga. Four of the sites are considered center city, six are in suburban locations, and two are rural. The height above ground of the monitors ranges from near ground level (7 feet) to 50 feet but the elevation above sea level varies considerably more - from 640 feet, the elevation of the city, to 2,140 feet on top of Lookout Mountain. The central city and industrial area of Chattanooga is surrounded by ridges, thus forming a basin where air quality concentrations tend to be uniform. Descriptions of the sampling sites are given in the section on Network Design and Monitor Siting.

The 1974 annual geometric means for TSP are shown at their respective sampling sites in Figure 2. Annual TSP concentrations exceeding the annual primary standard occur in the center city portions of Chattanooga east of the Tennessee River and west of Missionary Ridge. The highest TSP concentration, 101 $\mu g/m^3$, occurred at the site just north of the airport. Annual TSP concentrations just below the secondary standard were recorded at the suburban sites. The lowest levels occurred at two sites (sites 5 and 7) which were higher in elevation than the rest of the sites.

Five of the 12 sampling sites exceeded the national annual primary standard of 75 $\mu g/m^3$; the remainder recorded concentrations below the national annual secondary standard of 60 $\mu g/m^3$. The national 24-hour secondary standard was exceeded on 48 of the 697 sampling days (6.9 percent) at eight of the sites and the 24-hour primary standard was exceeded on 5 days (0.9 percent) at one sampling site - see Table 1.

The available historical air quality information is shown in Figure 3. The only site which has been operated for an extended period of time is the M & M site in the downtown area of Chattanooga. Annual TSP concentrations there have been declining since sampling started in 1958, from 215 $\mu g/m^3$ to 106 $\mu g/m^3$ in 1973. Another station, in Brainerd, has shown a decrease from 82 $\mu g/m^3$ to 60 $\mu g/m^3$ between 1966 and 1974. Six sites have been operated since 1971. The three sites recording the higher levels during that time showed an average decrease of 21 $\mu g/m^3$ while the other three sites experienced lower concentrations of TSP which appear to be merely fluctuating over time rather than increasing or decreasing.

Figure 2. 1974 annual geometric mean TSP concentrations

Table 1. SAMPLING SITES AND NATIONAL STANDARDS

Land use	Site number	Location	1974 TSP geometric mean	Number of days 24-hour standard exceeded	
				Primary	Secondary
Center City	1	City Hall Annex	80*	0	1
Residential	2	Signal Mountain	52	0	1
	4	Brainerd	60	0	2
	5	Lookout Mountain	38	0	0
	10	East Ridge	53	0	2
	12	Red Bank	56	0	0
Residential-Industrial	6	East Chattanooga	81*	0	6
Industrial	3	WDEF	86*	0	7
	9	Lovell Field	101*	5	15
	11	APC Bureau	84*	0	8
Undeveloped	7	Silverdale	38	0	0
	8	I-24 Welcome	55	0	0

* - Indicates that these sites exceeded the national annual primary standard of 75 $\mu g/m^3$ in 1974

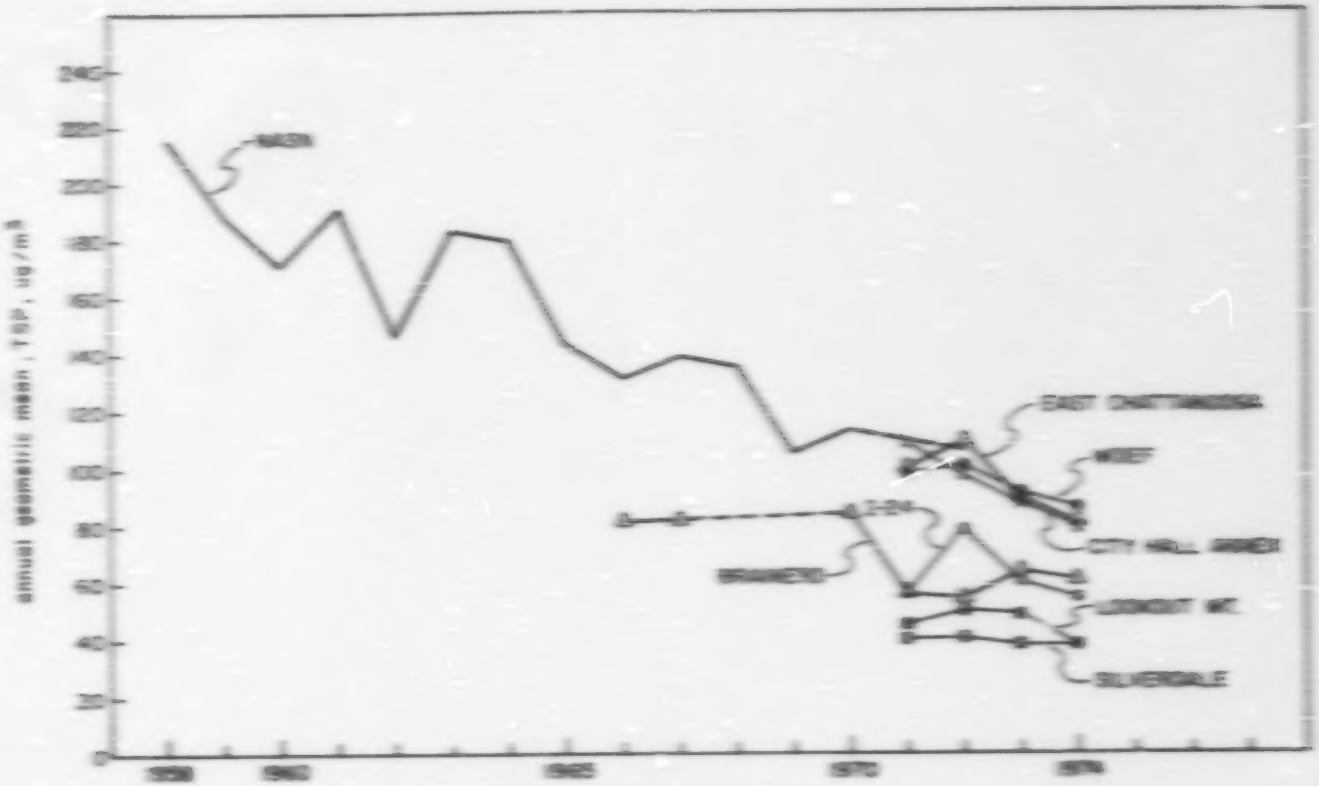

Figure 1. Trends in annual geometric mean TSP concentrations

REFERENCES

1. Tennessee State Implementation Plan, Chattanooga Section, 1971.

2. Local Climatological Data.

SECTION II

ANALYSES

EMISSIONS

The sources of particulate emissions in Hamilton County are shown in the 1975 emissions inventory in Table 2.[1,2] The most important category of sources is industry, both point and area sources, which together account for almost two-thirds of the total emissions. Within the category of industrial point source, which is one-quarter of the total emissions, industrial processes, especially in the food and agricultural, secondary metals, and mineral products industries, are the most important sources of particulates emissions. Industrial area sources, which include fugitive emissions, account for even more of the total emissions — about 40 percent — than do industrial point sources. The next most important category is fugitive dust which accounts for another quarter of the total emissions and includes dust from paved and unpaved roads, agricultural tilling, and construction.

Chattanooga is an industrial city with such heavy industries as foundries, cement, and heavy metals. It is apparent from the emissions inventory that industry is the largest source of particulate emissions and thus, it is the most influential with respect to TSP air quality. In fact, a comparison of citywide TSP concentrations by the day of the week on which they were recorded shows that TSP concentrations average about 20 $\mu g/m^3$ lower on weekends than on weekdays and are lowest of all on Sunday - See Figure 4. This points to a major industrial contribution to TSP air quality. Table 3 shows the 1974 emissions by the major industry types in Chattanooga.

Table 2. 1975 TOTAL EMISSIONS FOR HAMILTON COUNTY

	Emissions, TPY			% of total		
POINT SOURCES (INDUSTRIAL)[a]	3,881			24.8		
External combustion		770			4.9	
Industrial process		3,111			19.9	
Chemical			148			1.0
Food/Agricultural			892			5.7
Secondary metals			1,143			7.3
Mineral products			843			5.4
Other			85			0.5
AREA SOURCES[b]	11,774			75.2		
Residential		147			0.9	
Commercial/Institutional		101			0.6	
Industrial		6,141			39.2	
Transportation		1,420			9.1	
Gasoline motor vehicles			1,197			7.7
Diesel			73			0.5
Rail locomotive			74			0.5
Aircraft			6			
Off highway vehicles			70			0.5
Open burning		< 1				
Forest fire		6				
On-site incineration		56			0.4	
Fugitive		3,902			24.9	
Paved roads			1,950			12.5
Unpaved roads			944			6.0
Agricultural tilling			14			
Construction			994			6.3
TOTAL	15,655			100.0		

[a]From Chattanooga-Hamilton County APCB - industrial sources over 10 TPY

[b]From PEDCo Emissions Inventory - small (< 10 TPY) sources and estimates of area and unreported sources

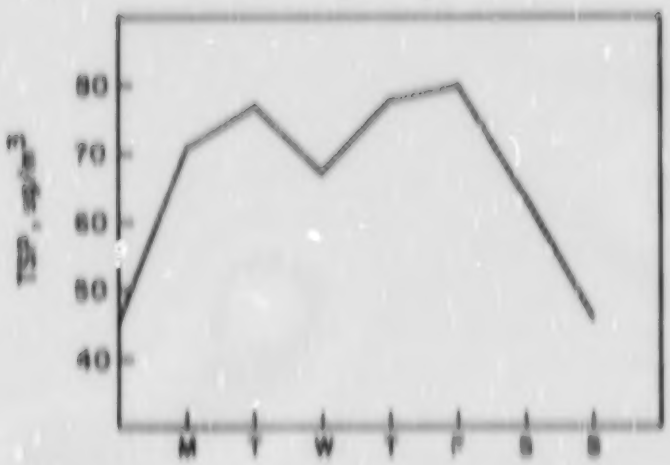

Figure 4. 1974 citywide mean TSP concentrations by day of the week

Table 1. 1974 MAJOR POINT SOURCE EMISSIONS BY INDUSTRY TYPE

	Number	Total emissions TPY	Average emissions TPY
Cement	1	1,800	1,800
Chemical process	2	1,265	633
Coke	1	300	300
Quarry	3	884	295
Grain	2	464	232
Foundry	6	919	153
Flour	1	77	77
Smelter	1	75	75
Reprocess paper	2	147	74
Conglomerate	1	62	62
Woodworking	2	96	48
Hospital	1	34	34
Drugs	1	33	33

Note: These figures are based on the 1974 emissions inventory which was revised for 1975 - some figures have been decreased

Source: C-HC APCB

The sampling sites nearest the industrial areas of Chattanooga have consistently recorded the highest TSP concentrations over the past years. Figure 5 shows the locations and emissions of the major industries with respect to the sampling sites and Figure 6 is a map of emissions density isopleths (see Network Design and Monitor Siting for sampling site descriptions.) Chattanooga is also influenced by point and area sources in Walker and Catoosa Counties in Georgia but the locations and emission densities of these are not available. The sampling sites in the downtown river valley area of Chattanooga - sites 1, 3, 6, and 11 - are nearest the industrial areas and had the highest 1974 geometric mean TSP concentrations. Site 9 is separated from the downtown river valley area by Missionary Ridge but it is located in another industrial area and has

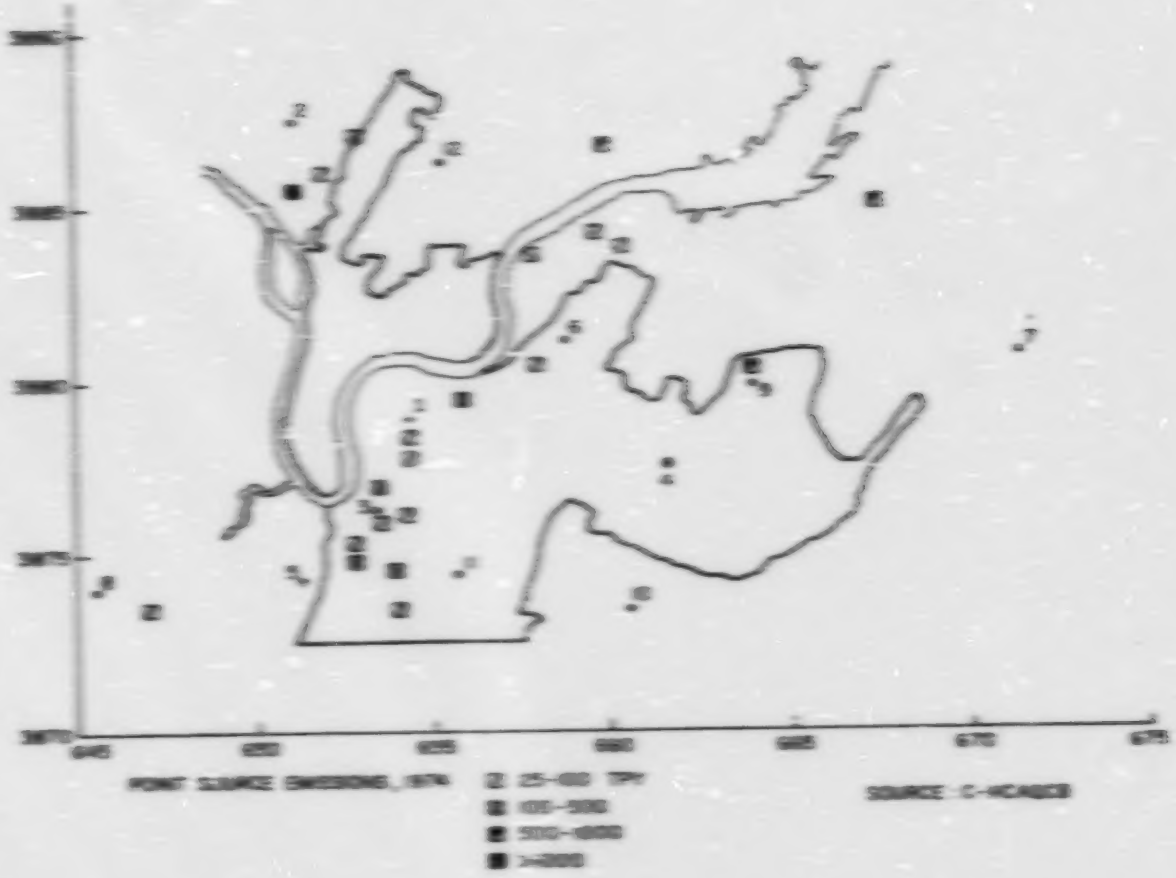

Figure 1. Point source emissions, 1974. Monitoring sites are indicated by site number

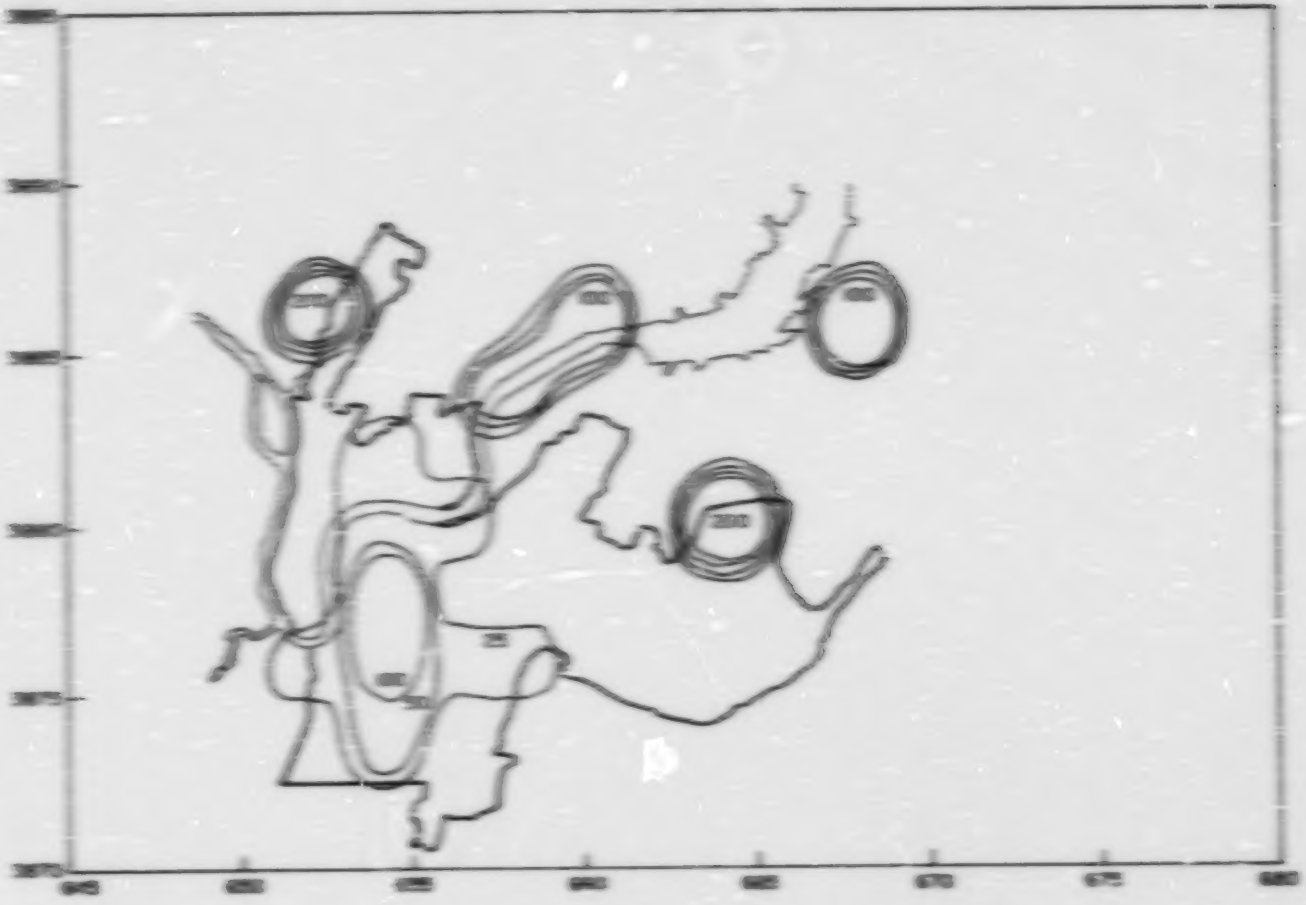

Figure 6. 1976 total emissions density isopleths, TPY/km^2 (includes all point source, residential, and automotive emissions). Source: CARB APCB.

also recorded high TSP concentrations. The rest of the sampling sites are either high above the industrial areas on ridges or mountains or separated from the industrial areas by ridges. These sites experience lower TSP concentrations and in 1974 achieved both annual standards. See Figure 2 for a map of the 1974 geometric mean TSP concentrations at the sampling sites.

There have been considerable reductions in emissions of particulates over the past several years. During the mid 1960s, the munitions industry, a major source of NO_2, was working at full capacity but has cut back production since then, especially since the end of the involvement in southeast Asia. In 1969, air pollution regulations were adopted and a two-phase time table for compliance was set up. Interim process emission standards were to be met by October 1972 and final process emission standards by July 1974. Most industries decided to meet the stricter standards by the interim date rather than use two successive and different sets of controls. Almost all of the industries are now in compliance with the process emission standards which has resulted in a large decrease in emissions since before the regulations took effect. The largest industries in Chattanooga - the foundries, coke plant, cement plant, and coal-fired boilers - accounted for more than half of the total emissions before compliance. Their emission reductions in compliance with regulations have had a considerable effect on total emissions in the city and on air quality. Since the start of the emissions reduction program in 1969, particulate air pollution has decreased, as is shown in Figure 3.

Process emissions of particulates which are directly emitted to the atmosphere through a stack, flue or other primary exhaust system have been reduced due to the air pollution control regulations. However, fugitive particulate emissions, those which escape indirectly through windows, doors, etc., and secondary particulates, those which are formed by the reactions of precursors in the atmosphere, have received less attention because there have been no effective regulations for them. These latter

sources include foundries and quarries and appear to comprise a significant portion of the remaining industrial emissions, but inventory techniques to verify this do not exist at this time. They should receive attention if industrial emissions are to be decreased further.

Emissions of particulates have also been decreasing due to trends in fuel usage. From 1924 to 1969, Chattanooga's air pollution program consisted of boiler inspection and smoke abatement which resulted in some fuel switching from coal to natural gas. Switching to the use of cleaner fuels continued when the Air Pollution Control Bureau came into existence in 1969. Tables 4 and 5 show the trends in residential and industrial fuel usage in Hamilton County. From 1950 to 1970, the number of dwelling units using gas has increased 462 percent and the number using electricity has increased 923 percent, while those using oil or coal have decreased 37 percent and 81 percent respectively. Coal was once used by 70 percent of the dwelling units for space heating purposes but now only 8.5 percent use coal. In industry, the usage of gas and oil has increased by 224 percent and 618 percent respectively from 1963 to 1972, while coal consumption has declined 18 percent. In general, then, fuel consumption has been changing over to cleaner fuels, resulting in less emissions of particulates.

Table 4: 1950-1970 RESIDENTIAL FUEL USAGE BY NUMBER OF DWELLING UNITS IN HAMILTON COUNTY

Fuel	1950	1960	1970	Δ1950-1960 as % of 1950	Δ1960-1970 as % of 1950	Δ1950-1970 as % of 1950
Gas	3,320	10,695	18,101	+233	+230	+462
Oil	7,405	6,075	4,629	-18	-19	-37
Coal	36,980	20,625	6,943	-44	-37	-81
Electricity	5,035	31,183	51,553	+519	+404	+923
Total	52,640	68,578	81,226	+30	+24	+54

Source: U.S. Census of Housing, 1950, 1960, 1970

Table 5. FUEL USAGE TRENDS IN CHATTANOOGA

Fuel	(Unit)	Industrial usage[a] 1963	1972	% Δ 1963-72	Electric utility usage[b] 1964	1973	% Δ 1964-73
Gas	10^6 ft^3	3,798	18,800	+224			
Oil	1,000 bbl	57	409.6	+618	NONE IN		
Coal	1,000 tons	318	261.6	-18	CITY (OR COUNTY)		
Coke	1,000 tons	33	--[c]		LIMITS		

[a]Source: Census of Manufacturers, 1963 and 1972, Fuels and Electric Energy Consumed (data is for SMSA level)

[b]Source: Steam Electric Plant Factors Book, 1965 and 1974, National Coal Association, Washington, D.C. (data is for CITY level)

[c]Not statistically valid

REGULATIONS, ENFORCEMENT, AND COMPLIANCE

The Chattanooga-Hamilton County Air Pollution Control Board is responsible for the jurisdiction over emissions into the air, preparation of regulations for the control of air pollution, establishment of standards for emissions, and enforcement of the standards in Hamilton County and the City of Chattanooga. The county program and its regulations are independent of the state's air pollution control program and regulations. Adoption of air pollution control regulations by all municipalities in the county is required for the regulations to take effect. The regulations pertaining to particulates are summarized in Table A-1 and Figures A-1 and A-2 in the appendix and are compared below with the regulations of other agencies for an understanding of their stringency.

The visible emissions regulation is the same as for most other agencies - 20 percent opacity. The allowable sulfur content of fuels - 4 percent - is higher than most other states'. The regulations for emissions from

new* incinerators, new fuel burning equipment and new process equipment are more stringent than most other states' regulations. The regulations for emissions from existing incinerators are less stringent than others and the regulations for emissions from existing fuel burning equipment and existing process equipment are average in stringency in comparison with other states.

The sulfur content of fuel regulation was 2 percent at one time but was raised to 4 percent because it was believed that the more lenient regulation would have little effect on the air quality since SO_2 levels in Hamilton County are extremely low.

Chattanooga has separate regulations for existing and new equipment. While the allowable emissions for new equipment are comparable to NSPS, the allowable emission rates for existing incinerators, fuel burning equipment, and process equipment are less than for new equipment and are average in stringency when compared with other states. Most sources, both existing and new, are using the best available control technology so that increasing the stringency of the regulations for existing equipment is unlikely to result in further air quality improvements.

There are also separate regulations for one or two family dwellings and larger buildings. Buildings with one or two dwelling units are not subject to the visible emissions regulation, the regulation prohibiting hand-fired fuel burning equipment, and the emissions from fuel burning equipment regulation. The estimated residential emissions, shown in Table 2, are less than 1 percent of the city's emissions so the differences in regulations for different size buildings is probably not important.

*New refers to sources built or installed on or after 1 January 1973, as opposed to existing sources which were in existence before 1 January 1973.

The Bureau has considered banning small incinerators but strong objections were raised locally which prevented a regulation from being adopted. At present, the Bureau controls the methods of incinerator operation by requiring all persons in charge of operating incinerators to be licensed. A license is obtained after a person has passed a test on his knowledge of the principles of incineration.

Open burning is allowed only with a permit and under certain restrictions. The Bureau has been giving fewer permits for open burning in and near the city in order to decrease the amount occurring. Open burning is allowed more frequently in more distant areas of the county where pickup service is inadequate or nonexistent. Open burning is allowed only on days when dispersion conditions are good.

Most point sources of particulates in the county are in compliance with the regulations and the remainder are under plans for compliance. Malfunctions which result in emissions in excess of that permitted are to be reported to the Bureau and are recorded in a log of "upsets". If it is felt that an industry has an excessive number of upsets, then the industry is cited and enforcement action is taken.

The fugitive emissions regulation is not very strong. The Bureau has had to rely on its nuisance regulation for controlling fugitive emissions from some industries. But some fugitive emissions problems cannot be enforced under either the fugitive emissions or the nuisance regulations.

Surveillance and enforcement are regular activities of the Air Pollution Control Bureau and have resulted in a high degree of compliance. Permits to operate require an inspection by the Bureau and must be obtained annually. Large companies, companies with emission problems, and those on variance timetables are inspected more frequently for compliance. Persuasion and public relations have been effective in getting most companies to comply with the regulations. If not, a company is cited and a hearing

before the Air Pollution Control Board is held, the result of which most times supports the Bureau's finding. Only a few cases have been challenged and have gone to court.

The procedure necessary for adopting regulations is time-consuming and involved - all municipalities in the county must vote to accept the air pollution control regulations for them to take effect and be enforced by the Bureau. It can be difficult, sometimes impossible, for the Bureau to gain acceptance for proposed regulations which some communities perceive as affecting them adversely. The Bureau is currently working on a regulation for air quality considerations in land use planning.

The Chattanooga regulations and the program of surveillance and enforcement have been successful in reducing process emissions of particulates and achieving a high degree of compliance. Further reductions in process emissions could be obtained if necessary by increasing the stringency of the regulations for old equipment. Fugitive emissions, however, are almost untouched by the regulations and, as discussed in the section on emissions, are believed to be an important source of particulates.

METEOROLOGY

As discussed earlier, the City of Chattanooga lies in an area which experiences low wind speeds and low-level temperature inversions with greater frequency than most geographical areas of the United States, and hence has a relatively high frequency of poor dispersion conditions. It was outside the scope of this study to attempt to explain either day-to-day or annual changes in TSP levels through detailed procedures, such as modeling which relies heavily on wind speed and stability inputs. On the other hand, one of the purposes of the study was to gain additional insight into the effects of precipitation and wind speed on TSP concentrations because of their impact on fugitive dust emissions and because of the part played by washout - factors which are not routinely accounted

for in many of the standard diffusion models. The results of this investigation, which is based in part on measurements made at City Hall in Chattanooga, are summarized in Volume I, the Final Report of this series of reports.

For this city report, graphs of easily-available standard meteorological indices have been plotted for comparison with monthly and annual TSP levels. These graphs are presented as Figures 7, 8, and 9. In addition, pollutant roses were prepared using 1974 data. These roses, which have inherent in them the fact that the TSP samplers are operated over 24-hour periods which usually contain significant changes in wind direction, are presented for five of the Chattanooga sites in Appendix A (Figures A-3 through A-7). Also included as Figures A-8 and A-9, respectively, are wind direction and precipitation roses based on 1974 sampling days.

Figure 7, a plot of monthly averages of city-wide TSP concentrations, wind speed, precipitation, and degree days, shows no consistent relationship throughout the year between TSP concentrations and any of these monthly indices. This does not necessarily mean that no physical relationships exist between the variables, but more likely that the relationships are complex and the indices crude. Figures 8 and 9 show, respectively, the annual amounts of precipitation and the number of heating degree days for the 20-year period from 1956 to 1975. Because of the short period during which a city-wide TSP sampling program has been operated, these figures are of principal use in showing the ranges experienced by these meteorological indicators over a 20-year period. The effect of variations in annual precipitation will depend on its distribution throughout the year. Volume I of the Final Report gives tentative estimates of the effects of changes in annual precipitation and degree days based on a regression analysis of 5-year data in 10 cities.

The pollutant roses generally show the highest concentrations with wind directions from the southeast at all sites. However, examination of

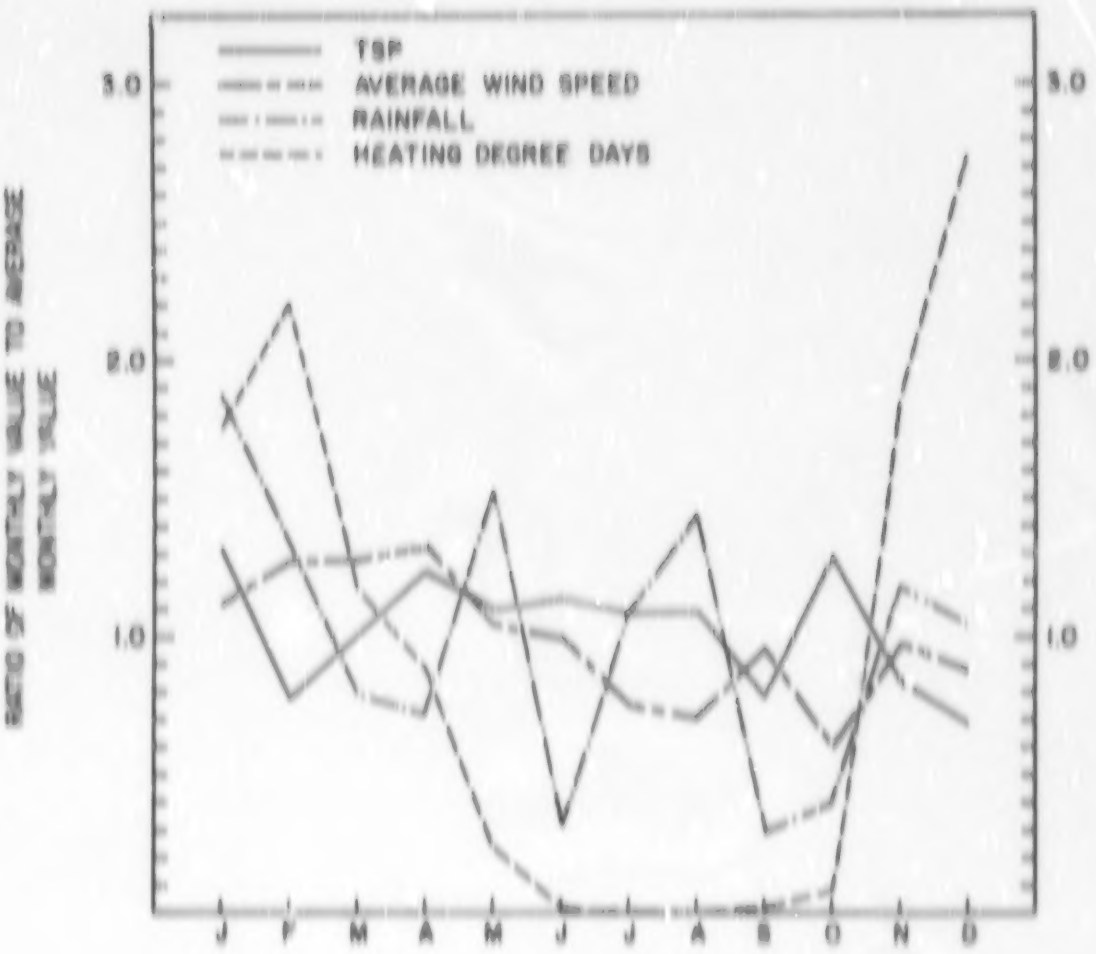

Figure 7. Monthly TSP versus meteorological variables, 1976

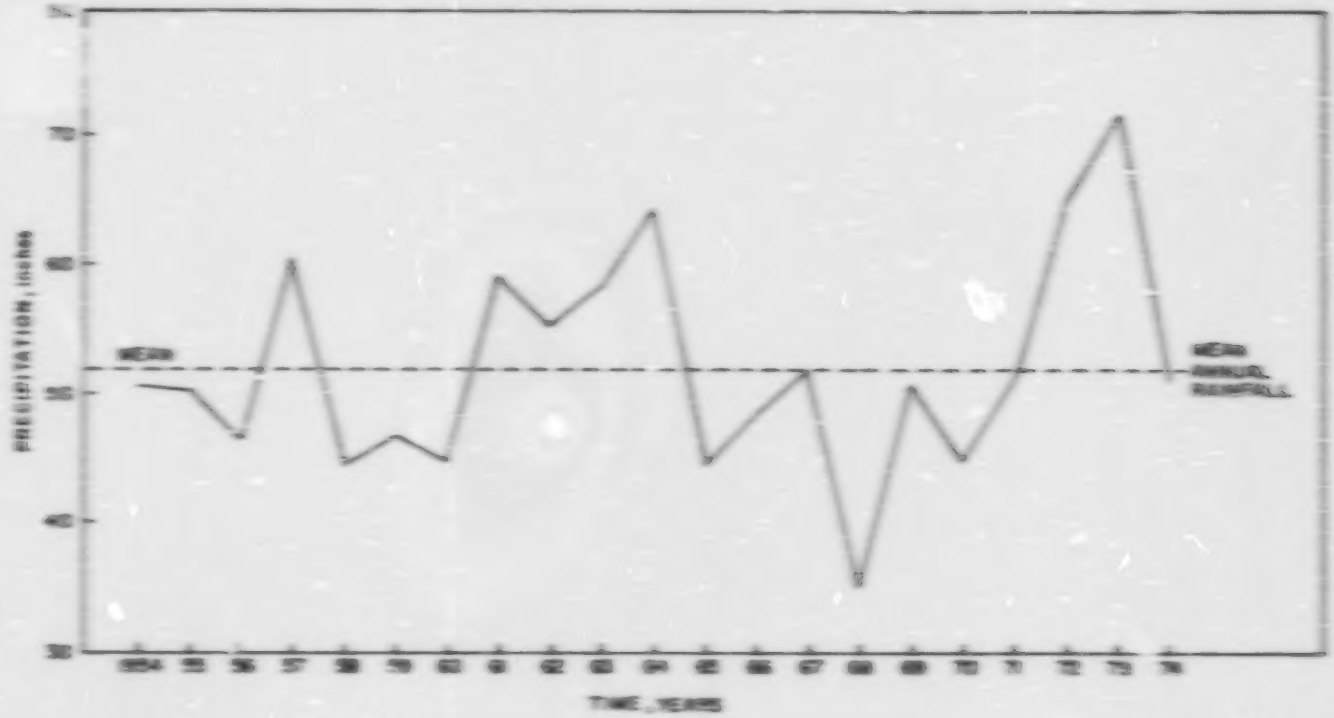

Figure 8. Annual precipitation versus time

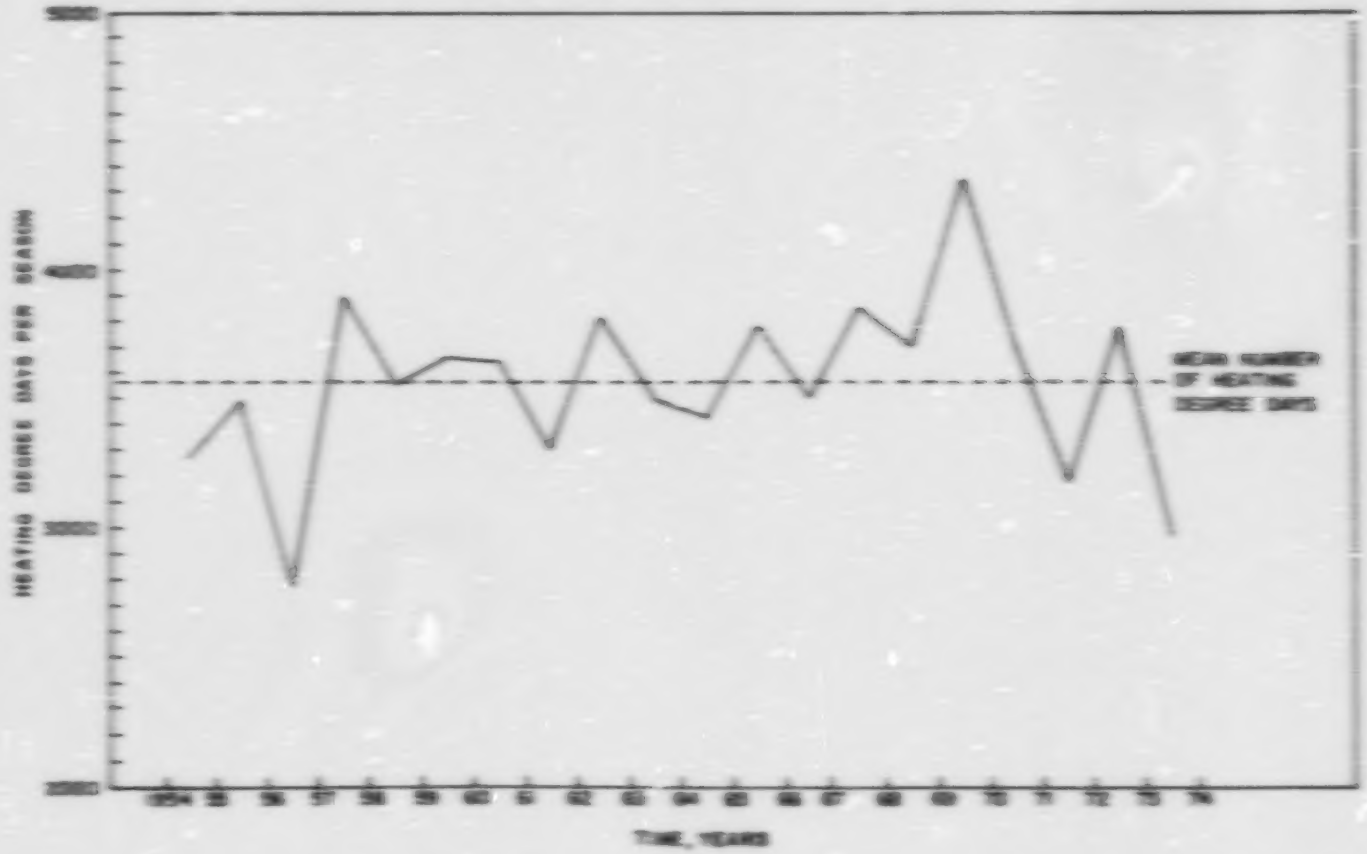

Figure 9. Heating degree days per season versus time

the wind rose shown in Figure A-8 shows that these relatively high concentrations are based on very few observations.

URBAN ACTIVITY FACTORS

Of the many urban activities which can influence TSP concentrations, the predominant one in Chattanooga is land use and development. While the contribution of traffic appears from the emissions inventory to be important (18.5 percent of the total particulate emissions), a comparison of TSP concentrations at several of the sampling sites with traffic counts on adjacent streets did not show a correlation. An exception is site 9 which is adjacent to a road from which material dropped from trucks is resuspended by passing traffic. At the rest of the sampling sites, however, traffic does not seem to be related to TSP levels. In addition, little construction and demolition has been occurring in Chattanooga.

Land use and the associated activities appeared to be the most important of the urban influences on TSP levels. The area of Chattanooga west of Missionary Ridge is industrial, commercial, and heavily residential, activities which contribute to higher TSP concentrations. In addition, this area is separated from other parts of the county by ridges so air quality tends to be uniform. The sampling sites located in this downtown area of Chattanooga - sites 1, 3, 6, 9 and 11 - experience the highest TSP concentrations and, in 1974, all exceeded the annual primary standard of 75 $\mu g/m^3$ - see Table 5. The other sampling sites are located in residential or undeveloped areas. Annual TSP concentrations at these sites are below the annual standards. Table 8 summarizes the specific land development in the vicinity of the sites.

Table 6. TSP VERSUS LAND USE

Predominant land use	Average of 1974 TSP geometric means	Sites
Center city	80	1
Industrial	90	3,9,11
Industrial-residential	81	6
Residential	52	2,4,5,10,12
Undeveloped	47	7,8

NETWORK DESIGN AND MONITOR SITING

The Hamilton County sampling sites are located in the southern portion of the county and mainly in and around the City of Chattanooga. The locations of the sampling sites are shown in Figure 1 and the sites are described in Table 7. Center city areas are represented by sites 1, 3, 6, and 11 in Chattanooga, suburban areas by sites 2, 4, 5, 10, and 12 in Chattanooga, Signal Mountain, and Lookout Mountain, industrial areas by sites 3, 9, and 11 in Chattanooga, and undeveloped areas by sites 7 and 8 in Silverdale and Tiftonia. Industry tends to be concentrated in the downtown area east of the Tennessee River and in the federal industrial area northeast of the city.

The design of the network is adequate for recording the variety of air quality situations in the southern portion of Hamilton County. The sampling sites seem to be well-distributed and representative of the different kinds of land development in and near Chattanooga. There are no sampling sites, however, in the northern portion of the county which is mostly undeveloped. It is desirable to have sampling sites in this large undeveloped section to determine background concentrations and the influence of the city. The Air Pollution Control Bureau recognizes the desirability of sampling in the north of the county but is unable to expand the network at present because the county already has the minimum number of sampling sites as suggested by EPA.

Table 7. [illegible]

[illegible] code	Local code	Location	Northing	Easting	Site characteristic	Height above ground	Start	Finish	Comments
[illegible]	1	City Hall Annex	3874.8	656.4	C-C	10	1970		Moved from P.O. in 1969
[illegible]	2	Ridgeway Drive	3867.7	651.8	S-R	12	1973		Moved from Valleydale Dr. in 1971
[illegible]	3	Hill, Israel Dr.	3874.9	655.2	C-I	10	1965		Moved in 1970 across the street
[illegible]	4	Countryside School	3877.2	648.8	S-R	20	1975		Moved from Shannon Dr. in 1975
[illegible]	5	Lookout Mt.	3874.7	655.2	I-R	3	1971		
[illegible]	6	East Chester	3881.*	658.9	C-C	25	1971		
[illegible]	7	Silverdale	3880.6	671.2	R-R	30	1971		
[illegible]	8	I-24 Welcome Ctr.	3874.2	665.6	R-R	12	1971		
[illegible]	9	Airport	3881.1	664.3	S-I	12	1975		Moved from Shallowford Rd. in 1975
[illegible]	10	East Ridge	3873.6	668.5	S-C	12	1972		
[illegible]	11	AFC Homes	3876.6	655.8	C-C	12	1972		
[illegible]	12	Red Bank	3886.2	655.3	S-R	7	1974		
[illegible]	(old 1)	U.S. Post Office	3873.1	656.3	C-C	65	1965	1969	Moved to City Hall annex in 1969
[illegible]	old	Shallowford Rd.			S-I		1973	1975	Moved to weather sta. at A.P. in 1975
[illegible]		U.S. Post Office	3873.1	656.3	C-C	65	1969		Main
[illegible]		801 Bellvue Dr.	3878.1	654.3	C	3	1966	1968	6521 8th Station
[illegible]	(old 2)	Valleydale Drive	3886.3	658.7	S-I	3	1970	1973	Moved to Ridgeway Dr. in 1973
[illegible]	old	Shannon Trail	3886.1	668.7	S-R	7	1965	1975	Moved to Countryside Sch. in 1975

The specific siting of the monitors seems in general to be adequate but varies widely in ways which influence the TSP concentrations recorded. Eight of the 13 sites were visited and descriptions of these are given in Table 8. The unusual characteristics of some of the sites and possible local sources are discussed below.

City Hall Annex, Site 1

The monitor is located on top of the City Hall Annex, a building four stories high in the central business district. A train yard and a flour mill are located with one-half mile of the site and the industrial section of town is a mile south. Traffic is heavy around the site.

Signal Mountain, Site 2

The site is on Signal Mountain, 5 miles northwest of the city. Several ridges and valleys, running in a northeast to southwest direction, are between the mountain and the city. The Town of Signal Mountain is about 1,100 feet higher than the City of Chattanooga. The largest source of particulate emissions in the county is about 1,000 feet lower than and about one and a half miles south of the sampling site.

WDEF, Broad Street, Site 3

The monitor is on top of a three-story building, 200 feet from a heavily traveled street. The site is in the industrial area of the city with several foundries less than one-half mile away. The base of Lookout Mountain is about one-half mile to the southwest.

Brainerd, Shavnee Trail, Site 4

The monitor was on the ground in a residential area with trees, shrubbery, and houses nearby.

Table 8. SAMPLING SITE DESCRIPTIONS

Site number	Location	Soil type (predominant series, type)	Predominant influence	Land use
1	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]

Lookout Mountain, Site 5

The site is on Lookout Mountain, a steep-sided plateau 1,500 feet above the city. The Town of Lookout Mountain is residential. The monitor is located 30 feet from the Incline Railway Station, near some trees and shrubbery, and almost on the edge of a cliff several hundred feet high. Frequent inversions occur in Chattanooga but the top of the mountain usually is above them.

East Chattanooga, Site 6

The monitor is located on top of a fire station, one story high, 50 feet from a street. The area is residential and commercial and a large train yard is about one-half mile west of the site. A local source is a supermarket incinerator. Traffic is medium on the major street and nearby streets are curbless.

Silverdale, Site 7

The monitor is on a fire tower surrounded by forests and on a low ridge. At the base of the ridge are cultivated fields and the federal industrial park is a couple of miles to the northwest.

Shallowford Road, Site 9

This is an industrial area, with a large quarry 2,000 feet west of the site, a batching plant nearby, Lovell Airfield to the south, and truck terminals surrounding. There are some unpaved roads. Material drops from trucks on Shallowford Road and is suspended by passing traffic. The monitor was moved to a different site in 1975 because the Shallowford Road site was considered to be too source-oriented.

Rossville Boulevard, Site 11

The monitor is located on top of the Air Pollution Control Bureau, one story high and 60 feet from Rossville Boulevard which is heavily traveled. The area is commercial and about a mile southeast of the city's industrial area.

The exposure of the monitors appears to be good, without obstructions by the building on which a monitor is located or by other surrounding buildings. The hi-vol on Lookout Mountain receives an especially long-range exposure because of its location on a high cliff. At several sites, a roof-top boiler stack is a possible local source. In general, however, the air quality recorded by the monitors seems to be representative of the air quality of the area in which each is located. The heights of the monitors are in the range of 1 to 50 feet. Those at ground level may be unduly influenced by strictly local sources or obstructions and those at 50 feet may be experiencing lower TSP concentrations than occur at lower levels due to decreasing TSP concentrations with increasing height. Most of the monitors are in the 12 to 30 foot height range which is reasonable. The characteristics of some of the sites are influencing the TSP readings -- five of the sites discussed in this section are in industrial or central city areas or near them, three sites are influenced by their elevation above and/or distance from the city.

REFERENCES

1. Chattanooga-Hamilton County Air Pollution Control Bureau 1975 Point Source Emissions Inventory. James Lents.

2. 1975 Area Source Emissions Inventory for Hamilton, Catoosa, and Walker Counties. PEDCo-Environmental Specialists.

SECTION III

SUMMARY AND CONCLUSIONS

SUMMARY

Air Quality Levels

Annual mean TSP concentrations in 1974 in Chattanooga range from less than 60 $\mu g/m^3$ at the suburban and rural sampling sites to around 80 $\mu g/m^3$ at the industrial and center city sites and 100 $\mu g/m^3$ at one industrial site. The national annual primary standard was exceeded by five sampling sites. The 24-hour primary standard was exceeded on 6.9 percent of the sampling days and the secondary standard on 0.9 percent of the sampling days.

Air quality levels in Chattanooga are influenced by several factors. Chattanooga is a highly industrialized city. The major point sources in the city, including foundries, quarries, a cement plant, and chemical processes, are among the most important sources of particulate emissions in the county. The sampling sites nearest the industrial areas (sites 1, 3, 6, 9, and 11) recorded the highest TSP concentrations in the county.

The topography of the area is complex, characterized by ridges and valleys running generally in a northeast to southwest direction. The industrial and downtown areas of the City of Chattanooga are surrounded by ridges, thus forming a basin where air quality levels tend to be uniform. In this area are found the highest TSP concentrations in the AQCR, with the exception of site 9 which is surrounded by industries. The rest of the sampling sites are located either on ridges or are separated by ridges

from the downtown Chattanooga area – these sites all recorded annual geometric mean TSP concentrations lower than the annual secondary standard in 1974.

Because of its topography, Chattanooga experiences meteorological conditions that cause poor dispersion of [illegible] pollutants. Low wind speeds and low-level temperature inversions occur with greater frequency in Chattanooga than most other areas of the United States. TSP, as well as other pollutants, tend to accumulate in the downtown Chattanooga area where the emissions are greatest.

Air Quality Trends

The sampling site which has been operated for the longest time, the NASN site in the center city area, showed a decrease in annual geometric mean TSP concentrations from 1958 to 1972 of over 100 $\mu g/m^3$. An average decrease of 21 $\mu g/m^3$ occurred from 1971 to 1974 at three center city sites. The other sites have not experienced an apparent decrease in TSP concentrations and appear mostly to be fluctuating over time around some mean.

Reductions in emissions have been responsible for the improvement in air quality with respect to TSP over the past several years. The air pollution control regulations, adopted in 1969, are considered to be stringent for new equipment and average for existing equipment. Surveillance of sources and enforcement of the regulations has been rigorous so that almost all of the point sources are in compliance. As a result, considerable decreases in particulate emissions from industrial processes have occurred since [illegible].

The type of fuel consumed has been changing. Coal consumption by homes and industry has declined significantly while consumption of cleaner fuels – oil, gas, and electricity – has increased.

The meteorological variables annual rainfall and number of heating degree days do not appear to be responsible for trends in TSP concentrations.

CONCLUSIONS

The small amount of historical data available indicates that air quality with respect to TSP exceeded the annual standards in Chattanooga in the past. This is due to the high degree of industrial activity in Chattanooga, the greater use of coal as a fuel, and the poor dispersion characteristics of the region. The NASN site since the 1960's and several center city and industrial monitoring sites since 1971 have shown decreases in TSP concentrations due to fuel switching, stringent regulations and vigorous enforcement, and industrial process emissions control. The sampling sites in the suburban and rural areas are meeting the standards because of the decreases in emissions and their locations in areas removed from downtown Chattanooga. The center city and industrial sampling sites, however, continue to exceed the annual standards. Poor dispersion, a relatively constant influence on Chattanooga's air quality, confines pollutants from the industrial sources to the downtown area which is surrounded by ridges. Fugitive emissions and dust and secondary particulates have not been controlled up to the present and are becoming a more important portion of TSP concentrations in Chattanooga as other sources are controlled.

APPENDIX A

SUPPLEMENTARY INFORMATION

Table A-1. CHATTANOOGA - HAMILTON COUNTY AIR POLLUTION CONTROL REGULATIONS

Rule 3 - Visible emissions with a density greater than Ringelmann number one or an opacity greater than 20 percent are prohibited. Buildings with one or two dwelling units are not subject to this regulation.

Rule 4 - Usage of fuels with a sulfur content greater than 4 percent is not permitted.

Rule 5 - The use of hand-fired fuel burning equipment with solid fuels is prohibited. Buildings with one or two dwelling units are not subject to this regulation.

Rule 6 - Open burning is prohibited, except under certain conditions relating to type of fuel, circumstances of burning, and pollution potential.

Rule 7 - The allowable emission rate of particulates from incinerators is 0.4 pounds per 100 pounds charge for old incinerators (existing before 1 January 1973) and 0.1 pounds per 100 pounds charge for new incinerators (built or installed on or after 1 January 1973). The opacity of incinerator emissions shall not exceed 20 percent or Ringelmann number one. New incinerators must be of the multiple chamber design. Incinerator operators must be licensed by the Bureau.

Rule 8 - The emission rate of particulates from new and old fuel-burning equipment is given according to the equipment rating (see Figure A-1). Buildings with one or two dwelling units are not subject to this regulation.

Rule 9 - Visible emissions from spark ignition engines are prohibited for more than 10 seconds or after vehicle start-up. Visible emissions from diesel engines greater than 20 percent opacity or Ringelmann number 1 are prohibited for more than 60 seconds.

Rule 10 - The emission rate of particulates from new and old process equipment is given according to the input process weight (see Figure A-2).

Table A-1 (continued). CHATTANOOGA - HAMILTON COUNTY AIR POLLUTION CONTROL REGULATIONS

Rule 11 - Particulate matter from materials handling or transporting in the open air shall not exceed Ringelmann 1. Reasonable precautions shall be taken to prevent particulate matter from becoming airborne.

Rule 14 - The discharge of air contaminants which causes a nuisance is prohibited.

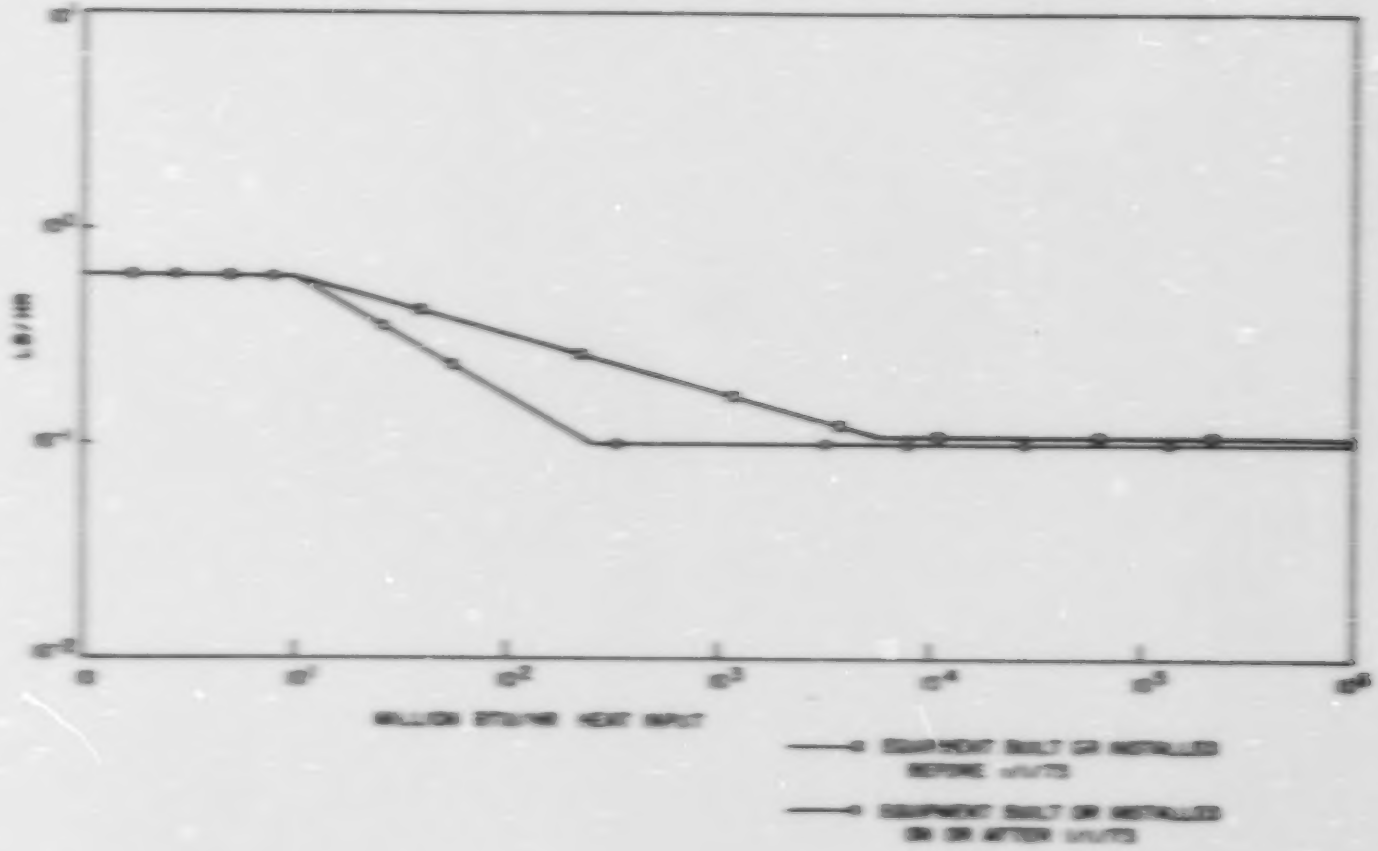

Figure A-1. Gastrenergy test burning equipment regulation

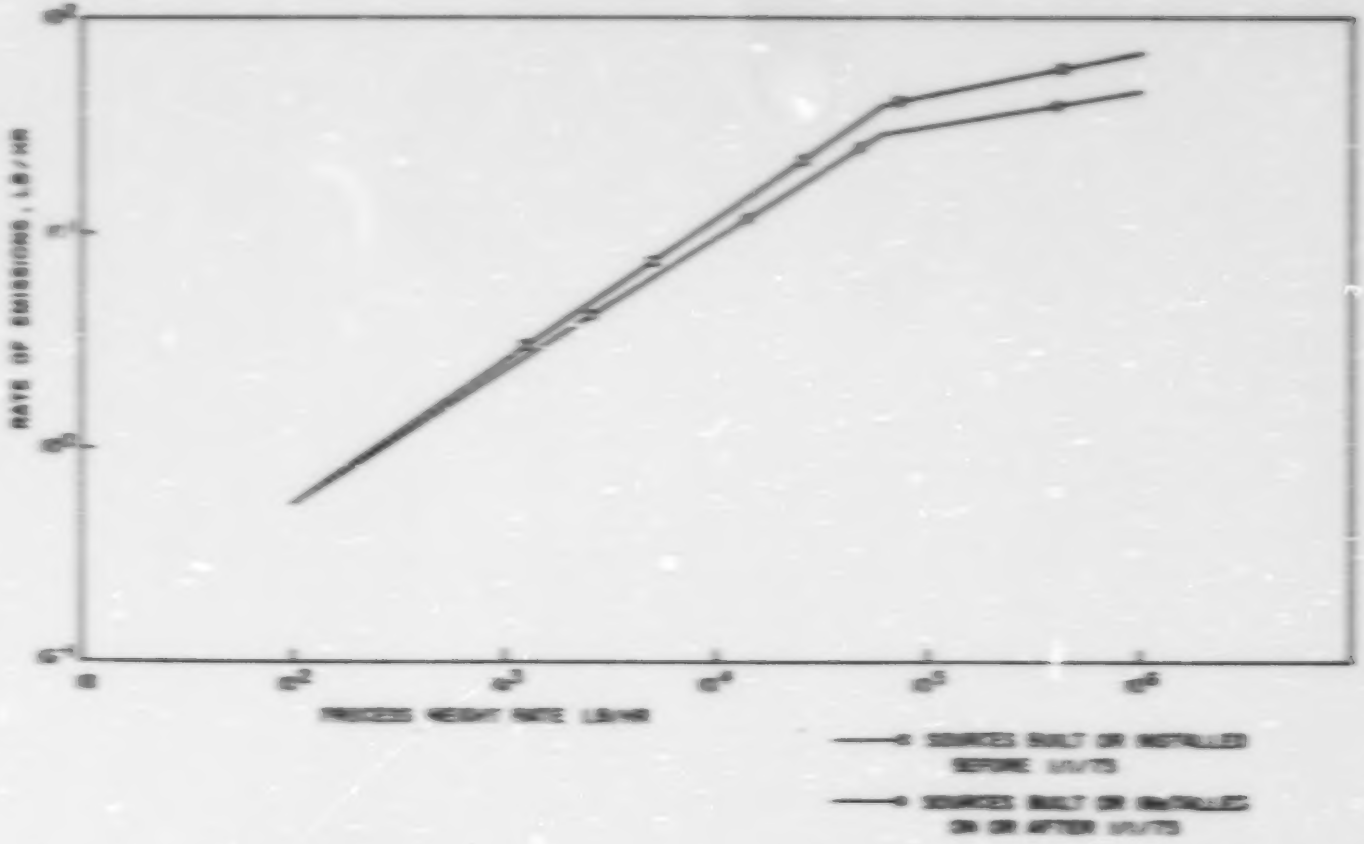

Figure A-2. Gastanaga process weight regulation

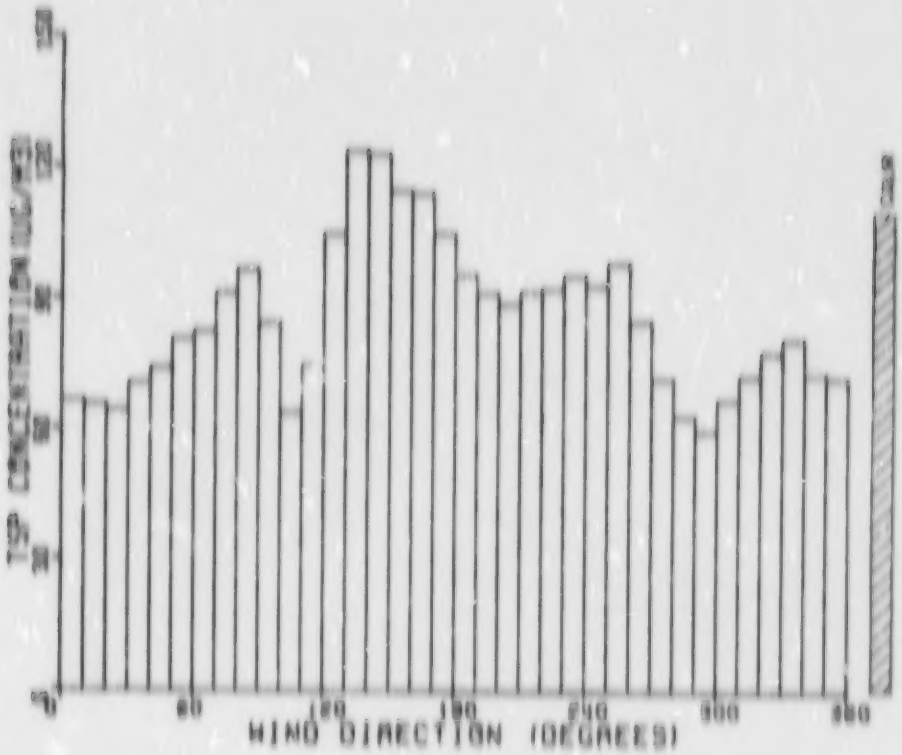

Figure A-3. TSP versus wind direction, Chattanooga city hall, site 1

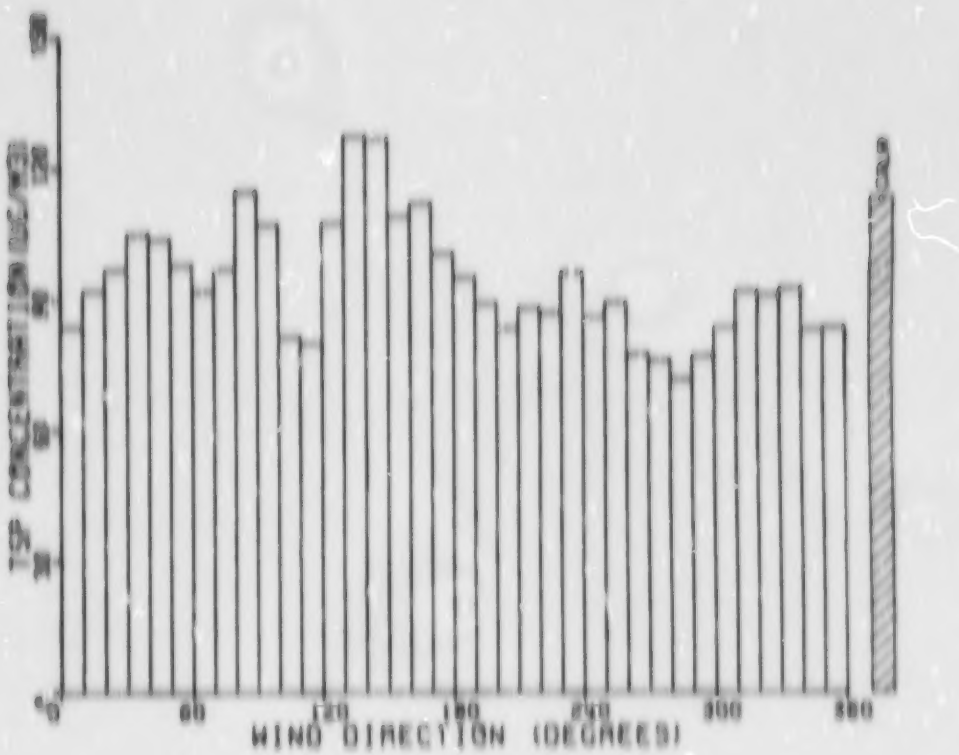

Figure A-4. TSP versus wind direction, Chattanooga Broad Street, site 3.

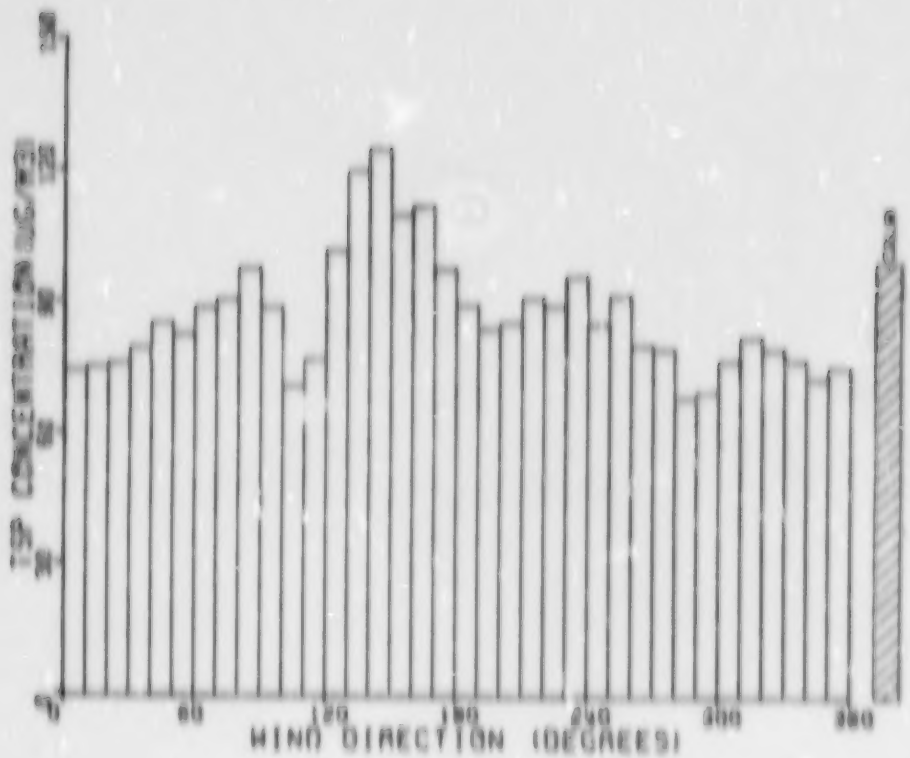

Figure A-3. TSP versus wind direction, Chattanooga East Chattanooga, site 6

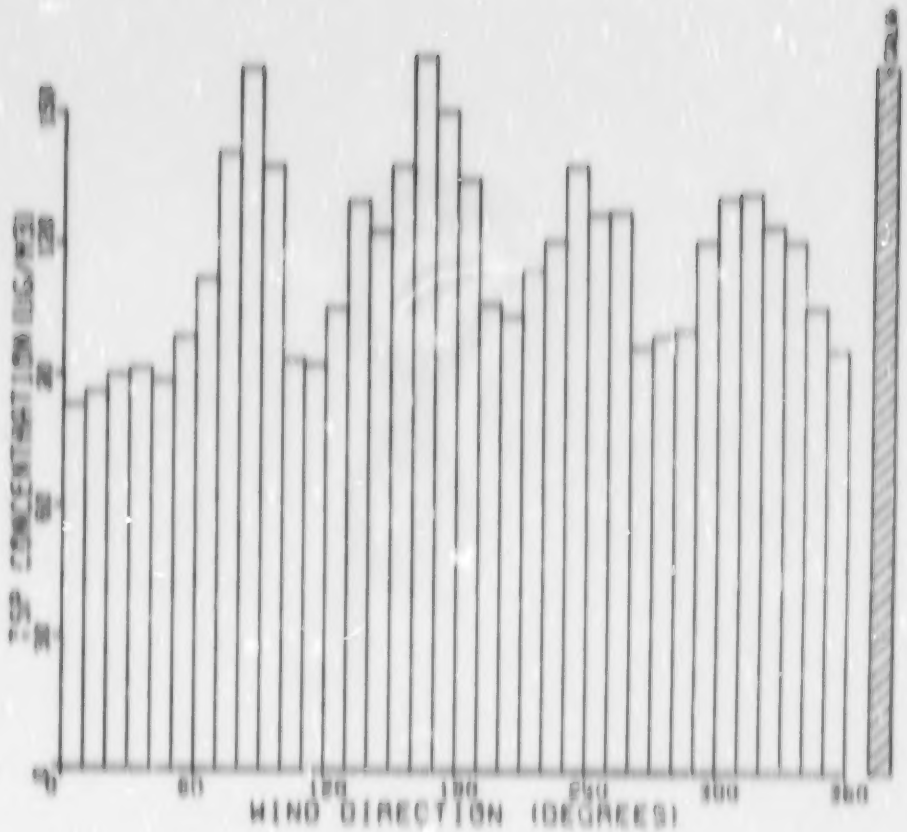

Figure A-6. TSP versus wind direction, Chattanooga Shallowford Road, site 9

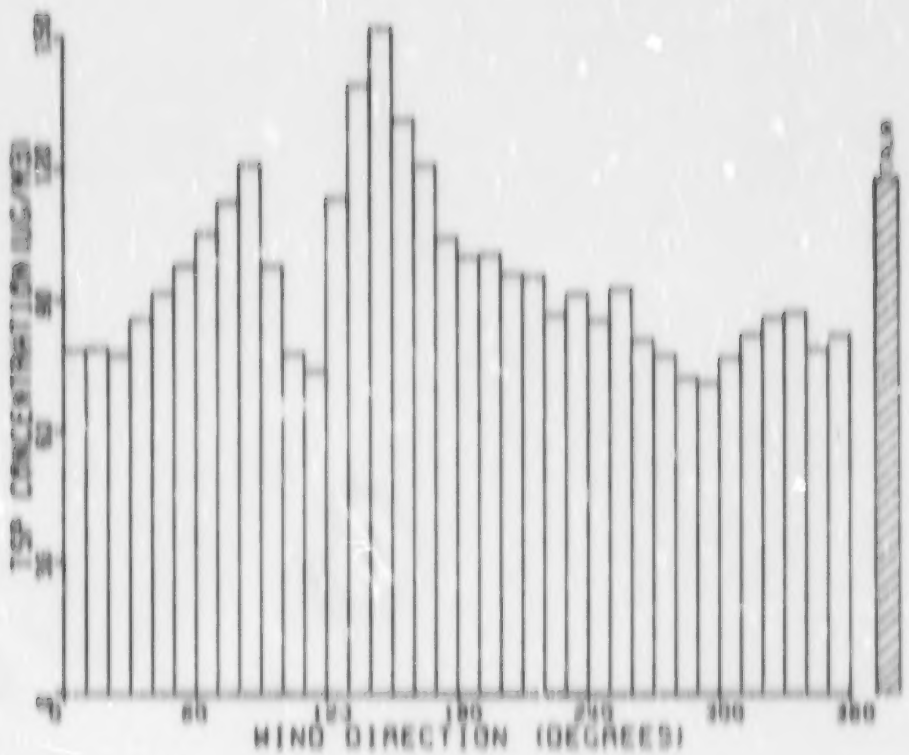

Figure A-7. TSP versus wind direction, Chattanooga Rossville Boulevard, APC Bureau, site 11

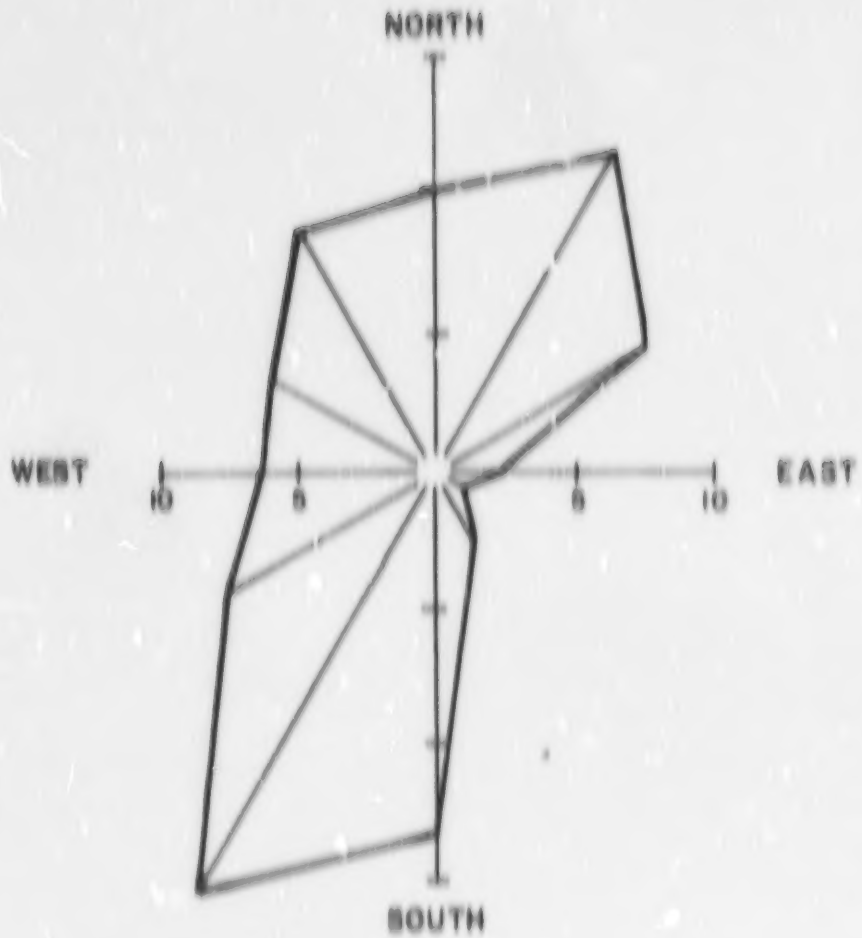

Figure A-6. Wind rose for the days on which sampling took place in 1974 - percent of observations

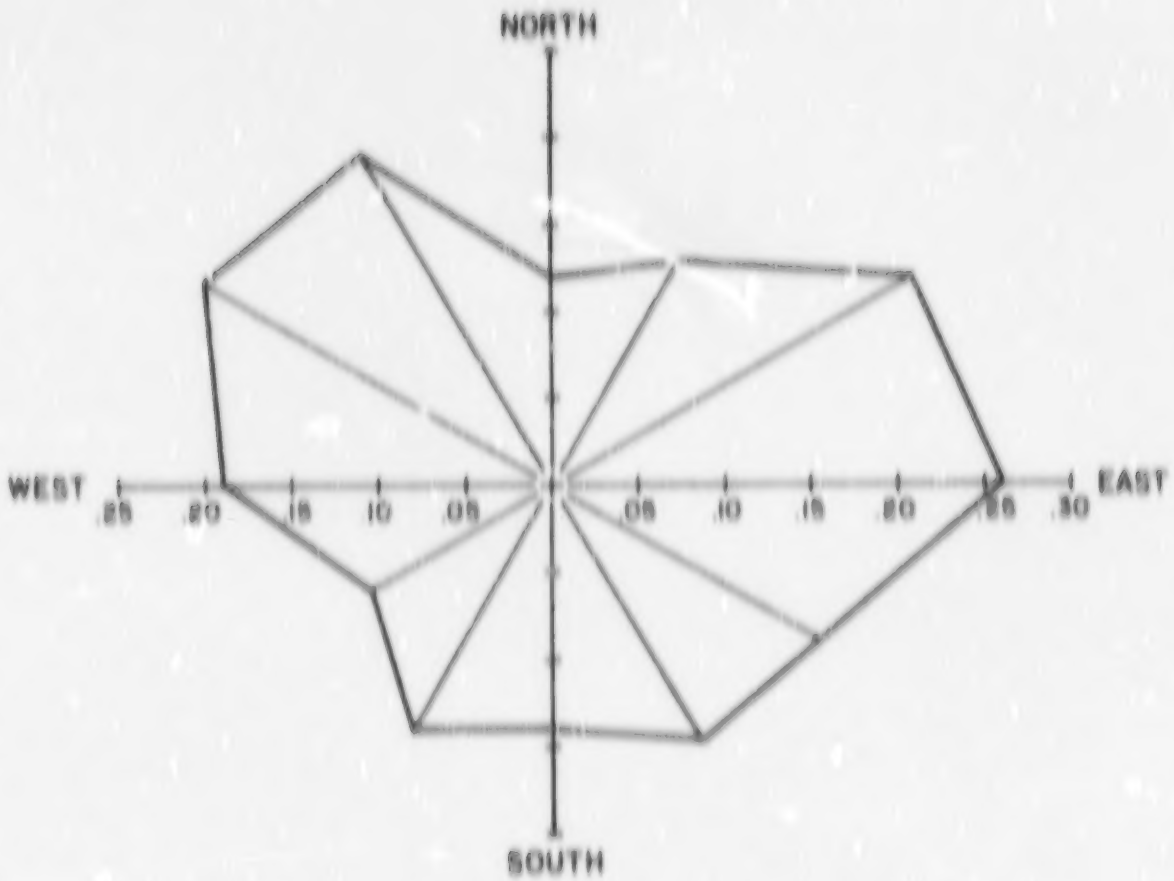

Figure A-9. Rain rose, 1974 average rainfall in inches by wind direction

APPENDIX B

PARTICLE CHARACTERIZATION

For most of the study cities members of the GCA study team acquired hi-vol filters from the 1976 filter banks of the cognizant local agencies. In addition, several filter samples for 1976 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than five percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any

one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Twenty-one filters from six sites were selected for analysis in Chattanooga and the meteorological data from Lovell Field for the selected sampling days are summarized in Table B-1. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table B-2. The results for each of the filters submitted for routine analysis are presented in Table B-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table B-4. Seven filters underwent replicate analyses, and the results are presented in Table B-5.

The composite particulate characterization for all filters from Chattanooga that underwent routine analysis, presented in Table B-6, shows that there are nearly equal amounts of minerals and combustion products, a very unusual observation. In all other study cities the mineral components comprised more than half of the observed particles, while in Chattanooga it averaged only about one third. There was an exception, however, at the Shallowford Road site where 96 percent of the material was mineral matter (nearly all calcite). This was undoubtedly the result of the local influence of a nearby quarry and trucking activities.

Chattanooga was ranked high (third highest) in average percent combustion products. The principal combustion product identified was coal soot with a lesser amount identified as incinerator fly ash. The presence of products related to coal combustion is understandable in view of the high coal consumption in the area. The material identified as incinerator fly ash is suspected of being the result of the many diverse industrial

processes (coking, smelting, founding, mineral products industries, etc.) prevalent in Chattanooga.

Biological materials were also very high in the area with Chattanooga averaging three times as much as any other study city. The Brainerd site averaged the highest percent biologicals but nearly all filters that were examined from April or May showed substantial levels of pollen and miscellaneous plant tissue. Chattanooga also ranked high in average percent rubber (13 percent) with only one other city recording higher levels. The Broad Street site, which is located near a heavily traveled highway, averaged 20 percent rubber. Lesser but still significant amounts of rubber were found at the City Hall and Brainerd. It is interesting to note the extremely high levels of rubber observed on December 13, 1974 at City Hall and Brainerd. If the microscopy results are a reliable indicator of the makeup of all the particulate collected on the hi-vol filters, then the rubber concentration at City Hall and Brainerd on that date would be 41 $\mu g/m^3$ and 34 $\mu g/m^3$, respectively.

Table B-1. METEOROLOGICAL DAT. ON SELECTED SAMPLING DAYS (LOVELL FIELD, CHATTANOOGA)

Date	Precipitation (in.)		Wind speed (mph)		Wind direction (deg)	
	Day of obs.	Preceding day	Average	Resultant	1-hour observation	Result ant
1/ 1/79	0	0	10.1	10.0	0; 0; 0; 0; 170; 160; 170; 160; 160; 160	180
4/29/76	0	0	6.5	4.9	0; 0; 0; 0; 80; 150; 160; 160; 70; 80	140
7/11/76	0.48	0.10	6.8	3.6	50; 50; 50; 150; 160; 160; 50; 150	110
10/30/76	0	0	1.7	0.9	0; 0; 1; 0; 0; 350; 350; 0; 0; 0	310
12/17/76	0	0	4.6	1.5	170; 0; 0; 190; 80; 160; 350; 0	170
12/31/76	0.32	0.01	5.8	5.7	0; 0; 0; 0; 10; 10; 20; 10	310

NOTE: 0 = Calm

Table B-2. ANNUAL AVERAGE CONCENTRATION OF SULFATE AND NITRATE IONS AT THE CHATTANOOGA, TENNESSEE NASN SITE NO. 440180001 ($\mu g/m^3$)

Yr	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	12.30	10.79	2.29	2.10
1973	11.65[a]	10.56[a]	2.35[a]	2.03[a]
1974	11.51[a]	10.82[a]	2.05[a]	2.29[a]

[a]Indicates insufficient data for statistically valid mean.

[illegible]

[illegible]

| [illegible] | [illegible] | [illegible] |

Table 9-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CHATTANOOGA AND VICINITY (BROAD STREET - NO. 3)

	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
Components	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

| | | |

Table 9-36. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CHATTANOOGA AND VICINITY (EAST CHATTANOOGA – NO. 6, SILVERDALE – NO. 7 AND SHALLOWFORD ROAD – NO. 9)

Site	East Chattanooga – No. 6			Silverdale – No. 7			Shallowford Road – No. 9		
Date	13 December 1976			26 October 1976			7 April 1976		
TSP ($\mu g/m^3$)	171			76			352		
Components	Concentration, ng/m³	Concentration, ng/mg	Avg. Conc., ng/m³	Concentration, ng/m³	Concentration, ng/mg	Avg. Conc., ng/m³	Concentration, ng/m³	Concentration, ng/mg	Avg. Conc., ng/m³
Phenol	15	<1430	7	11	<1420	4	(24)	<1440	8
Guaiacol	1			2*					
Catechol	4						9*		
Methoxyphenol									
Methylcatechol									
Resorcinol									
Eugenol									
Isoeugenol									
Dehydroabietic acid	15	<1440	8	10	<1420	4	(24)		
Retene									
Methoxybenzoic acid									
Vanillin									
Acetosyringone									
Syringaldehyde	3*								
Isovanillin	2*			1*					
Acetosyringone									
Syringic acid									
Methyl syringate									
Coniferaldehyde									
Sinapaldehyde									
Benzo[a]pyrene	(3*)			(3*)			(3*)		
Perylene									
Coronene									
Benzo[ghi]perylene									
Anthanthrene									
Dibenz[a,h]anthracene									
Indeno[1,2,3-cd]pyrene									
Benzo[b]chrysene									
Picene									
Dibenzo[a,e]pyrene	(3*)			(3*)			(3*)		
Dibenzo[a,h]pyrene									
Dibenzo[a,i]pyrene									
Dibenzo[a,l]pyrene									
Coronene									
Benzo[ghi]perylene									
Anthanthrene									
Dibenz[a,h]anthracene									
Indeno[1,2,3-cd]pyrene									
Benzo[b]chrysene									
Picene									
Dibenzo[a,e]pyrene						

Table 1-4. [illegible]

Site	[illegible] No. 1	[illegible] No. 2	[illegible] No. 4	[illegible] No. 6	[illegible] No. 7	[illegible] No. 8
No. of Samples	4	4	4	2	2	2
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Constituent	Average / Range	Average / Range	Average / Range	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 3-5. RESULTS OF REPLICATE ANALYSES OF CHATTANOOGA FILTERS

Site	[illegible] — No. 1							[illegible] — No. 2			[illegible] — No. 4		[illegible] — No. 7		[illegible] — No. 9	
Date	29 April 1965			13 May 1965		27 December 1965		29 April 1965			27 December 1965		29 December 1965		22 April 1966	
TSP ($\mu g/m^3$)	185			84		46		134			179		79		133	
Collocation	A		B	A		A		A		B	A		A		A	
Analysis	1	2	1	1	2	A	B	1	2	1	1	2	1	2	1	2
Constituent																
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]				[illegible]		[illegible]		[illegible]								
[illegible]						[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]																
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]							[illegible]			[illegible]		[illegible]		[illegible]	
[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table B-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN CHATTANOOGA

No. of filters	31	
	Quantity, percent	
Components	Average	Range
Minerals	(36)	1-96
Quartz	10	<1-30
Calcite	16	2-93
Feldspars	8	0-20
Hematite	2	0-12
Mica		
Other	<1	0-1
Combustion Products	(35)	8-78
Soot:		
Oil	7	0-40
Coal	14	0-40
Misc. soot		
Glassy fly ash	5	0-76
Incinerator fly ash	9	0-26
Burned wood		
Burned paper		
Magnetite		
Carbon black		
Other		
Biological Material	(16)	0-90
Pollen	7	0-25
Spores	<1	0-2
Paper	<1	0-2
Starch	1	0-5
Misc. plant tissue	8	0-80
Leaf trichomes		
Miscellaneous	(13)	0-45
Iron or steel	<1	0-4
Rubber	13	0-45
Other		